Roughness & Mannings n-value

Channels and Floodplains

Culverts

Teaching Objective

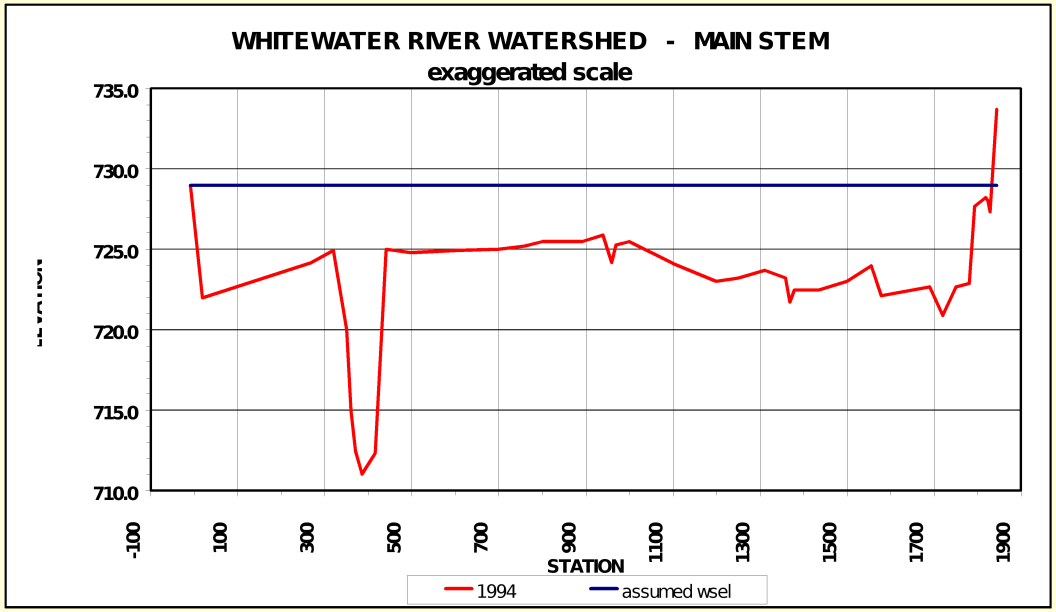
- Understand that:
  - resistance to flow depends on roughness
  - Manning's n value is simply a parameter used by hydraulic engineers to represent roughness
  - Roughness changes with time (e.g. brush growing in channels, culverts aging & deteriorating)
- Learn how "n" values affect hydraulic parameters
- Obtain basic information on choosing or calculating n values

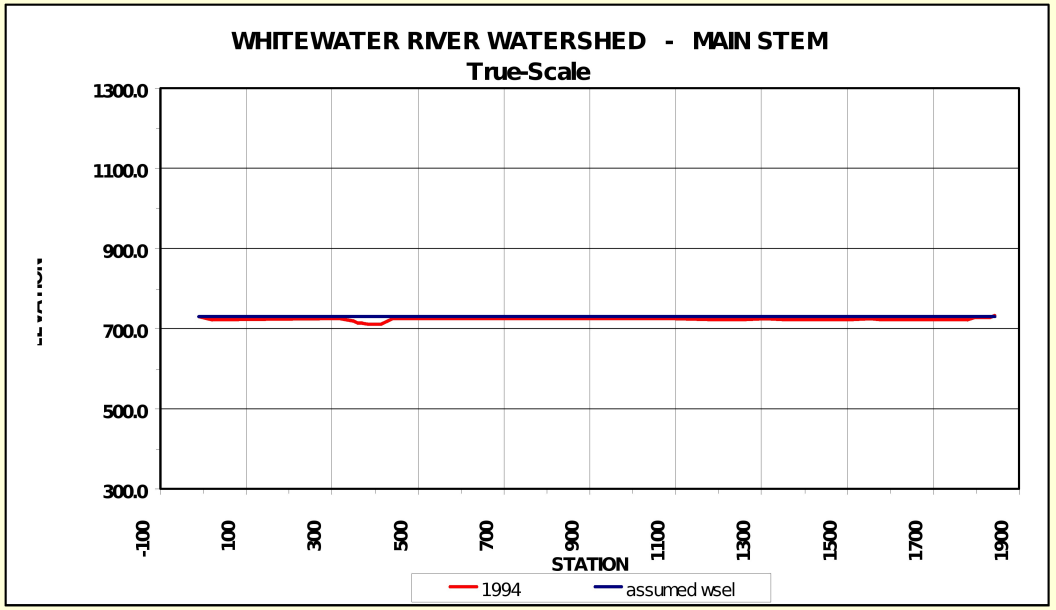
Application

- From an analytical standpoint, Mannings n value is a coefficient that needs to be chosen to calculate or model flow
- Used for both culverts and open channels

Significance

- From a practical standpoint, roughness affects all of the characteristics of flowing water (flow, velocity, water surface elevation) and therefore affects sediment transport, flooding, navigation, ecosystem restoration, etc.….
- The significance of roughness becomes more apparent, perhaps, when we compare a cross section plotted on an exaggerated scale to the same cross section plotted on a true scale.


WHITEWATER RIVER WATERSHED - MAIN STEM
exaggerated scale
735.0
730.0
725.0
720.0
715.0
710.0
-100
100
300
500
700
900
1100
1300
1500
1700
1900
STATION
1994
assumed wsel


WHITEWATER RIVER WATERSHED - MAIN STEM
True-Scale
1300.0
1100.0
900.0
700.0
500.0
300.0
-100
100
300
500
700
900
1100
1300
1500
1700
1900
STATION
1994
assumed wsel

Channel with Vegetation

- Riparian vegetation has a significant effect on roughness values for this channel during a flood

Manning Equation for Velocity

$$v = \frac{1.49\ R^{0.67}\ S^{0.5}}{n}$$

where, v = velocity, ft/sec
n = roughness, $s/ft^{1/3}$
R = hydraulic radius, ft
S = hydraulic slope, ft/ft

Note: If R increases, v increases
If s increases, v increases
If n increases, v decreases

Example of what happens to velocity if we change variables in Mannings equation

$$v = 1.49R^{2/3} s^{1/2} / n$$

	R	s	n	v
Example >>>	5	.0001	.03	1.46
If R is doubled	10	.0001	.03	2.32
If s is doubled	5	.0002	.03	2.06
If n is doubled	5	.0001	.06	.73

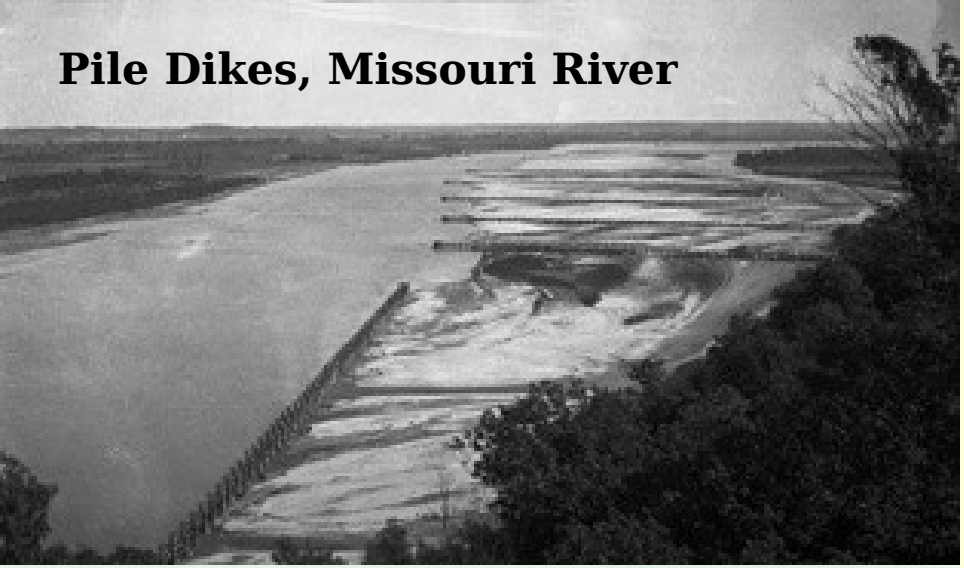
Guidance exists for choosing n values

- USGS, Water Supply Paper 1849, Barnes

Hydraulics Handbooks & Textbooks

The table below is from Vennard & Street, pg 470

Corrugated Pipes	.024
Concrete pipes, open channels	.013
Small channels, clean	.03
Large channels (width > 100’	.025
Floodplains (natural vegetation)	.06 -.1



Structures have been used to change roughness in rivers

Jetty Jacks, Rio Grande floodplain Albuquerque, NM

Culverts

Galvanized Steel

- Old pipe with new extension

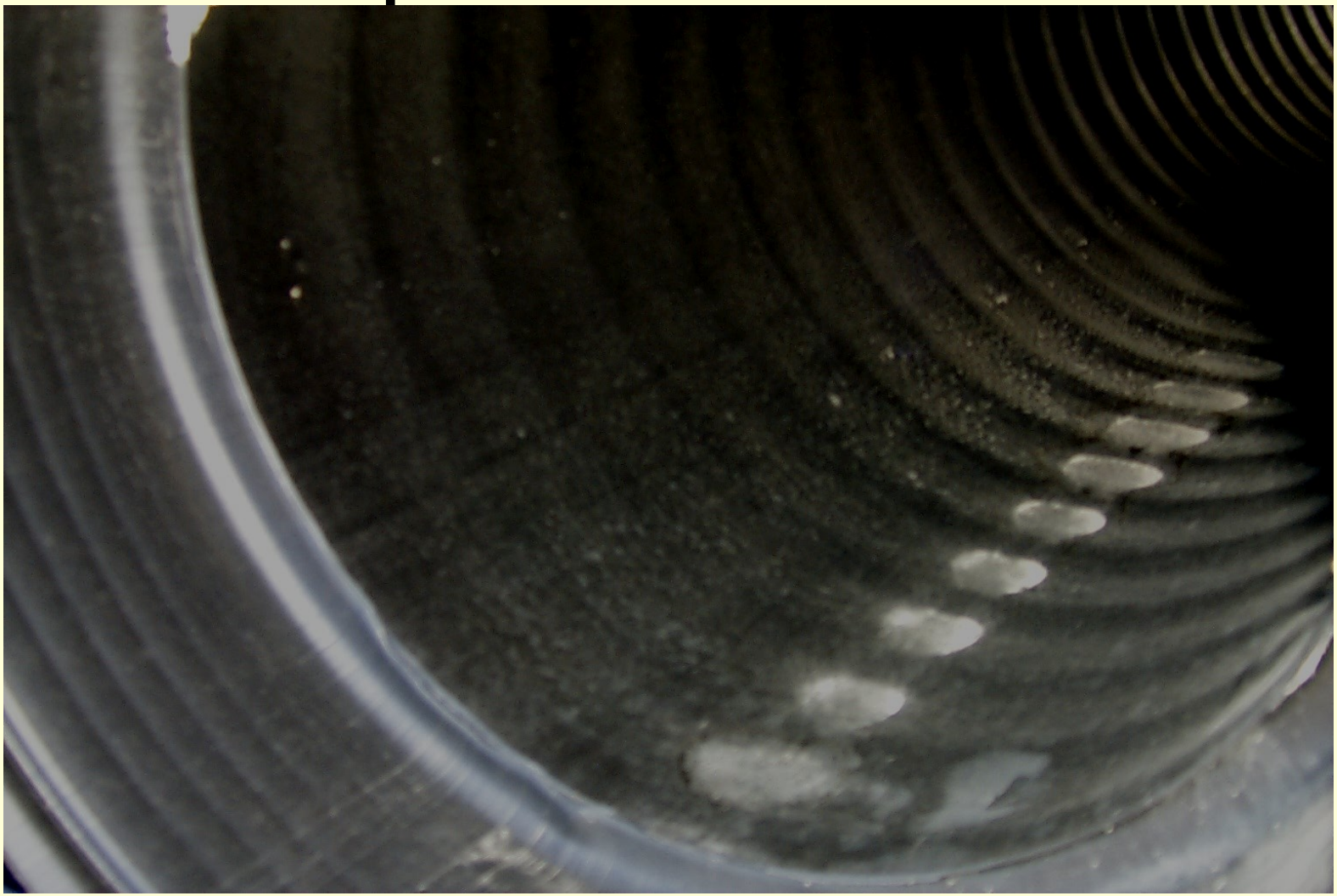
Concrete Pipe

Wooden Pipe

District 1 in Duluth

State Highway MN 23

Plastic Pipe



“Smooth Plastic” dual wall HDPE has slight corrugations. PVC (no photo available) would also be “Smooth Plastic”

Channels & Floodplains

Riprap in Open Channels

- n-value is based on a representative size of the substrate gradation,such as the D50. D50 is the sediment diameter at which 50% of the weight of a sediment sample is made up of particles of smaller diameter
- the bigger the representative size, the greater the n-value

The Strickler relation between Manning n and mean particle size d_{50} (feet). (From Chow, 1959):

$$n = 0.0342\, d_{50}^{1/6}$$

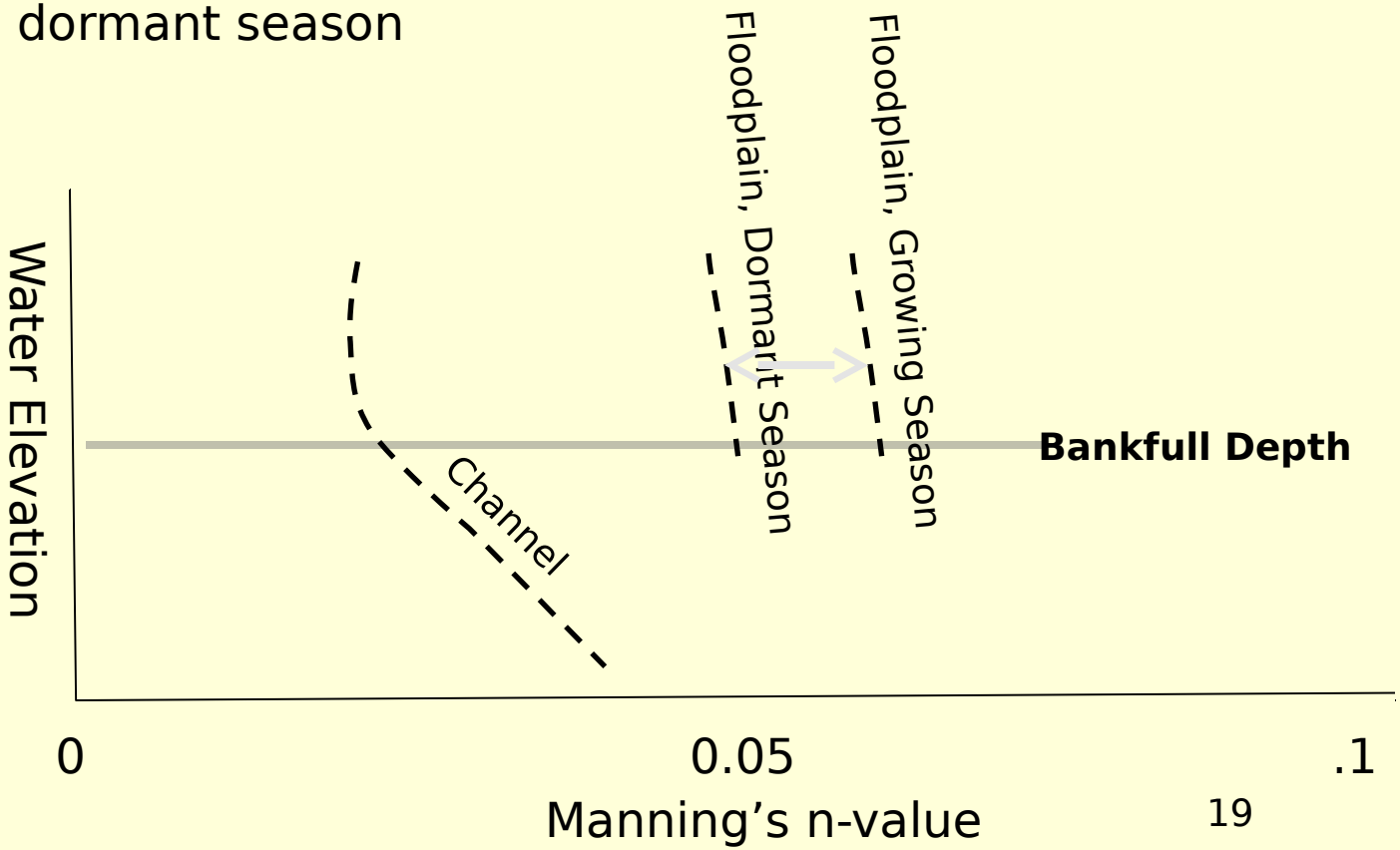
Riprap Roughness

D50 = 0.5' n = 0.035
D50 = 1.0' n = 0.040
D50 = 2.0' n = 0.044

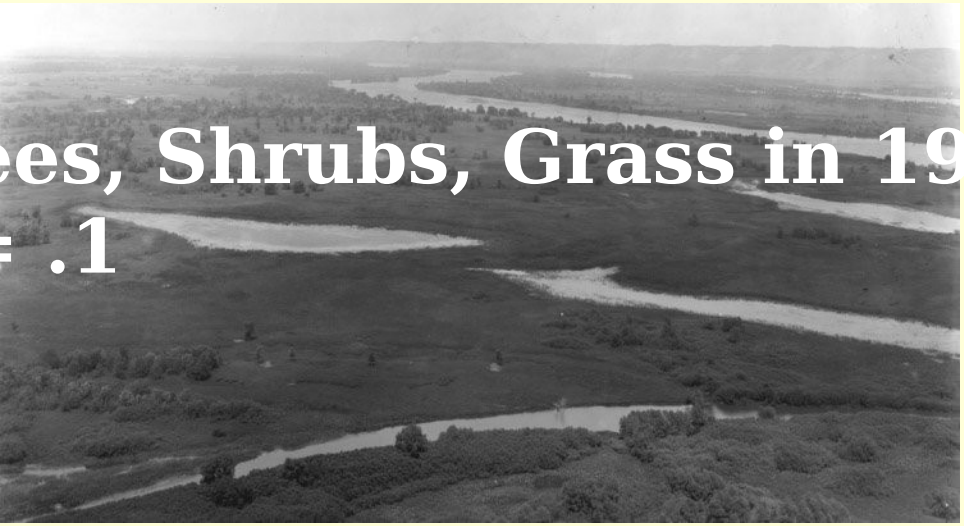
- doubling the representative riprap size does not double the n-Value

Variation in n-value

- As depth increases, channel n-values usually decrease, though there could be exceptions to this (see Chow, pg 104).
- n-values in the floodplain and along channel banks may increase during the growing season and decrease during the dormant season



Change in floodplain features and Manning's n with time (Upper Mississippi River)



$$v = \frac{1.49\ R^{0.67}\ S^{0.5}}{n}$$

As n decreased, v increased resulting in more flow in the Floodplain over time

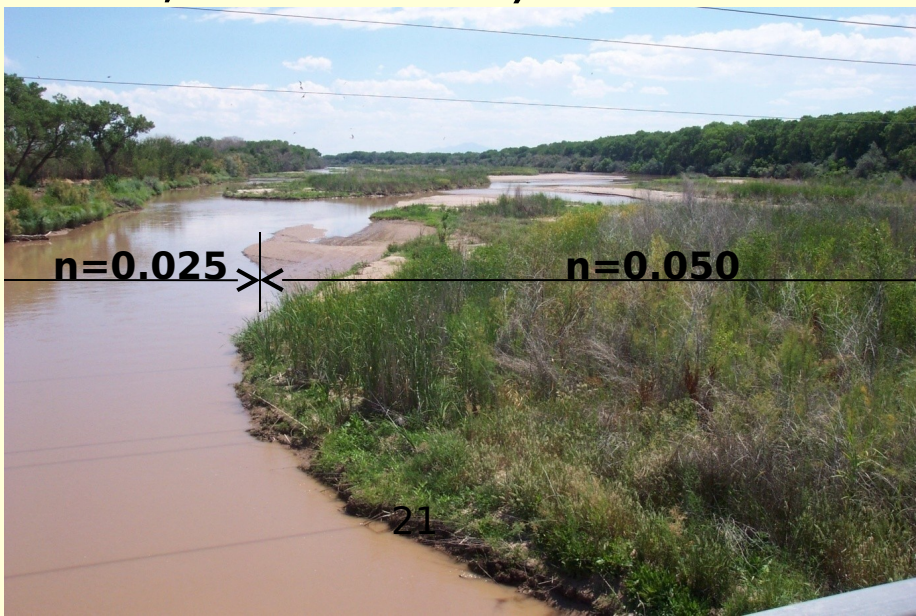
Composite n Values

- Complex channels may have several different n-values

- Horton Method: Applies to a single cross section, which represents a reach's 6 components (listed below). Used in HEC-RAS (see Ch. 2, Pg 2-6 HEC-RAS users manual, version 3.1, Nov 2002)

1. earthen material
2. regularity of a given section
3. regularity among sections
4. obstacles
5. vegetation
6. sinuosity

$$n_c = \left[\frac{\sum_{i=1}^{N} (P_i n_i^{1.5})}{P} \right]^{2/3}$$

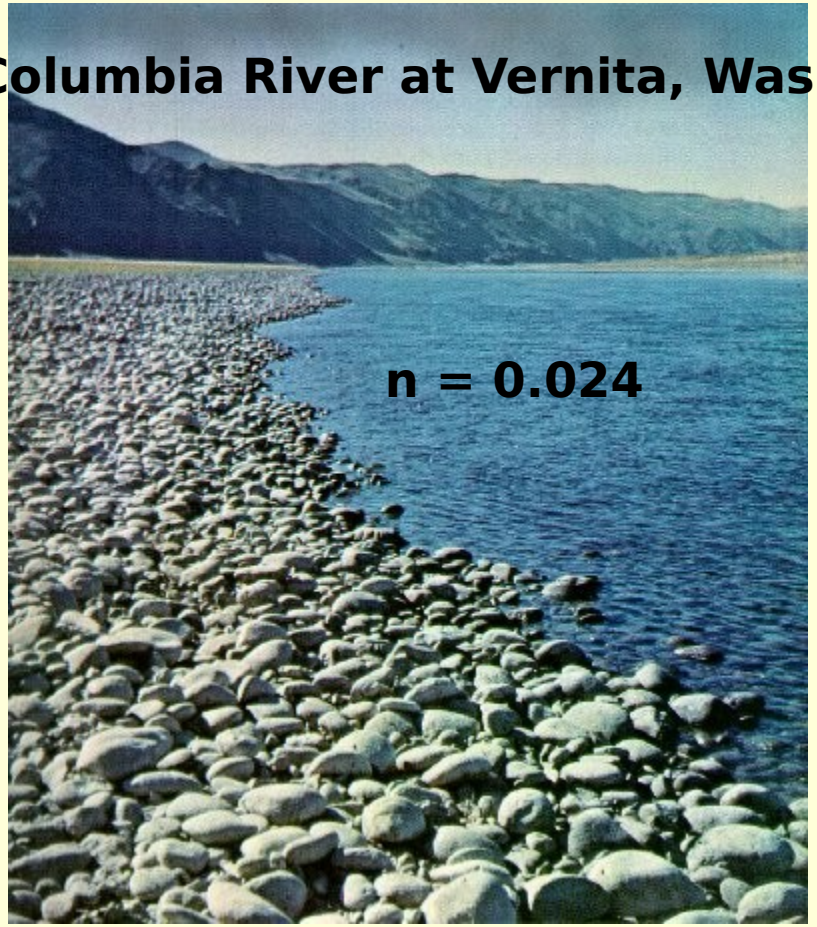


Stability/Capacity Design in Open Channels

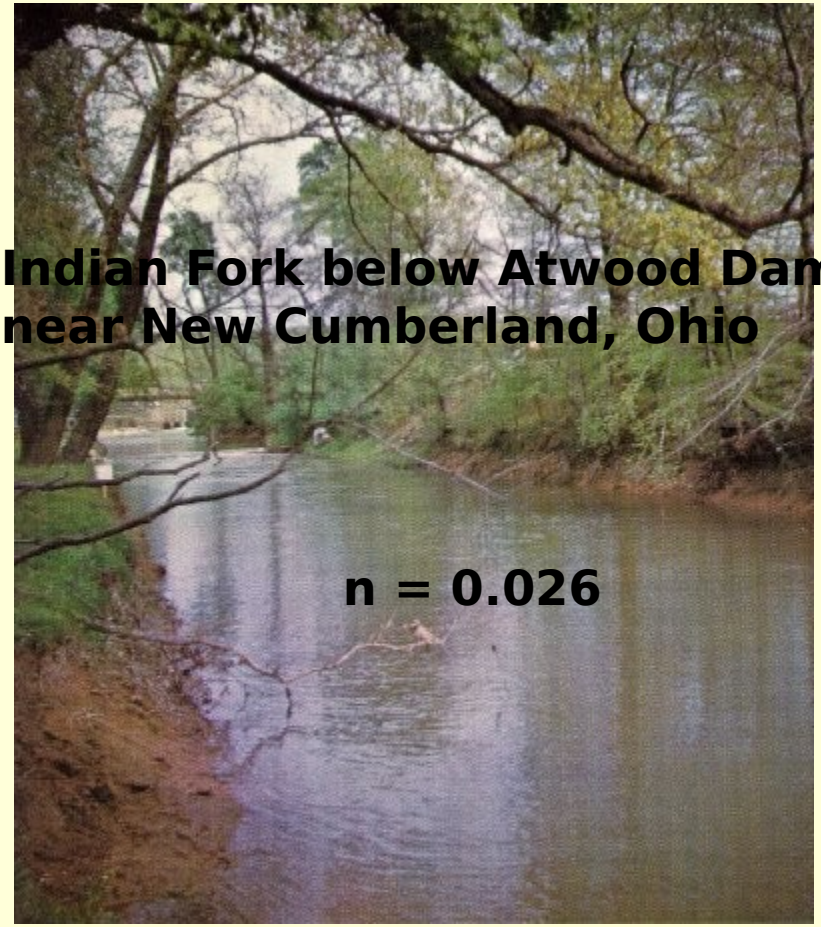
- Stability can be assessed by using an n-value slightly lower than the estimated n-value.
  - calculated velocity will be greater, area will be less, the flowline will be lower, and there will be a greater tendency for erosion

- Capacity can be assessed by using an n-value slightly greater than the estimated n-value
  - calculated velocity will be less, area will

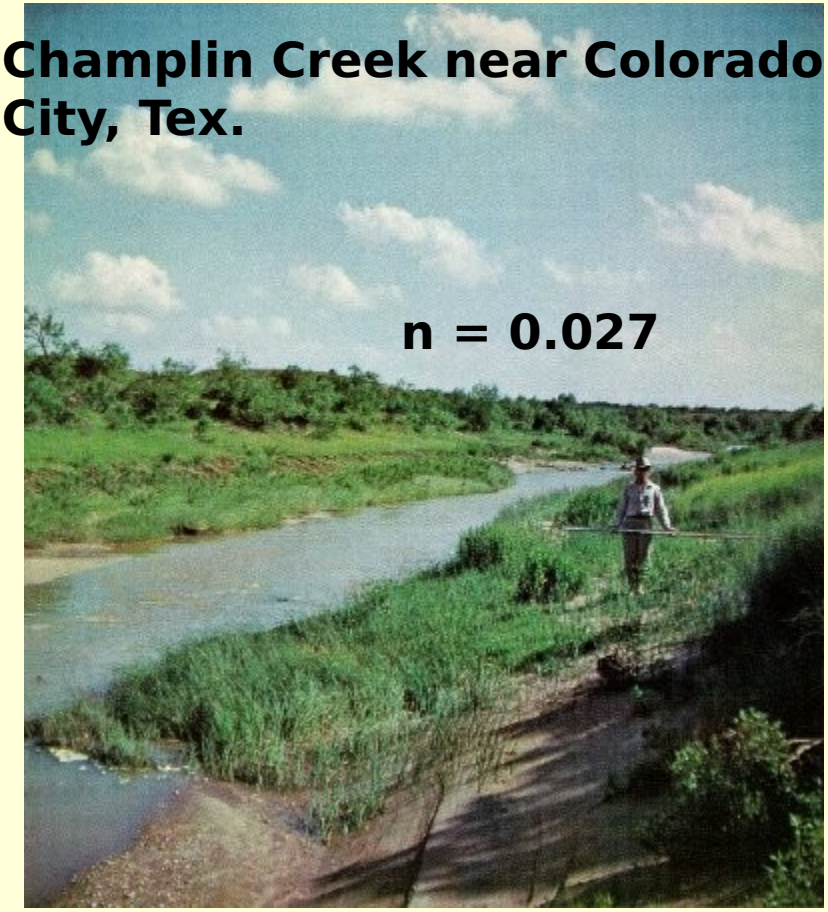
Columbia River at Vernita, Wash.

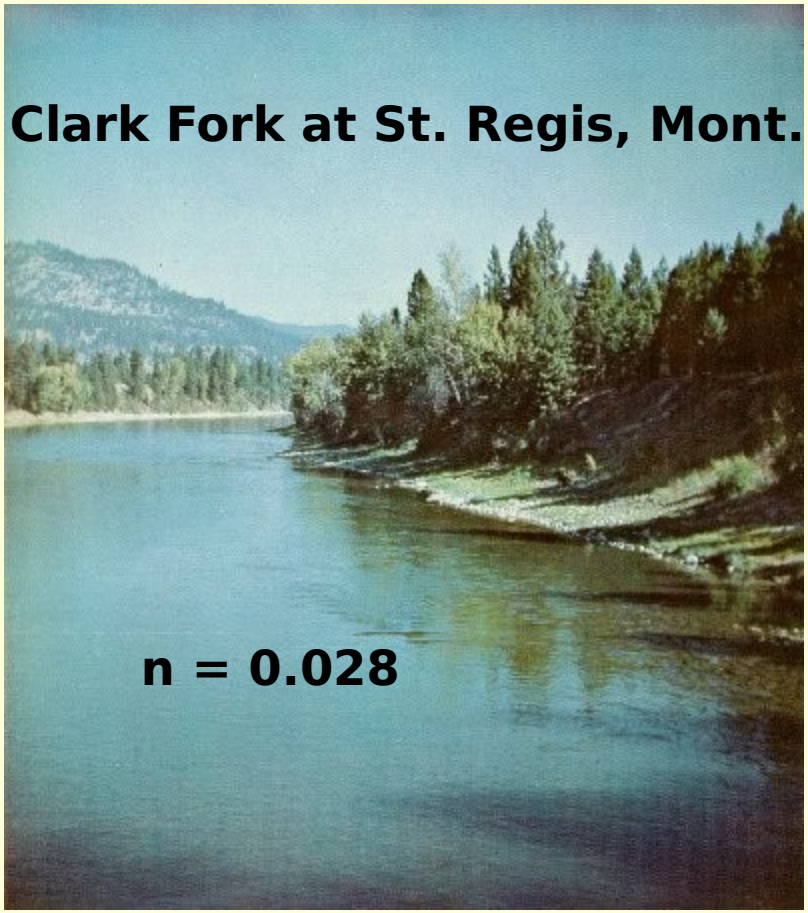


Indian Fork below Atwood Dam, near New Cumberland, Ohio



Source of Information:
Roughness Characteristics of Natural Channels
U.S. Geological Survey Water Supply Paper 1849
By Harry H. Barnes, Jr.





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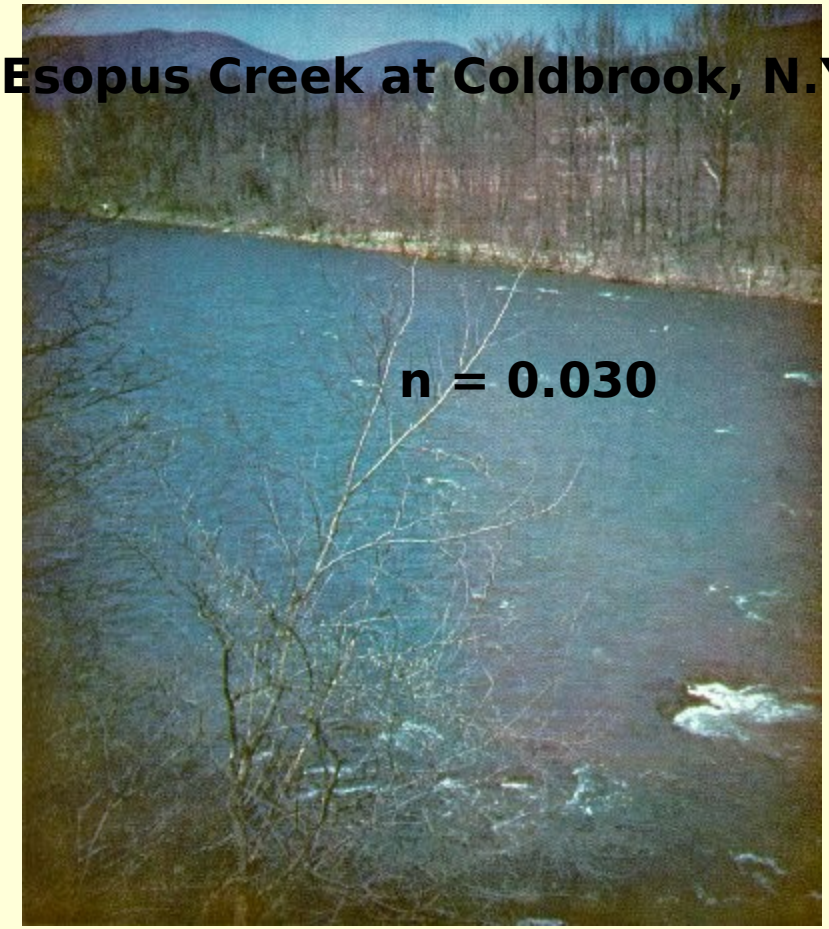

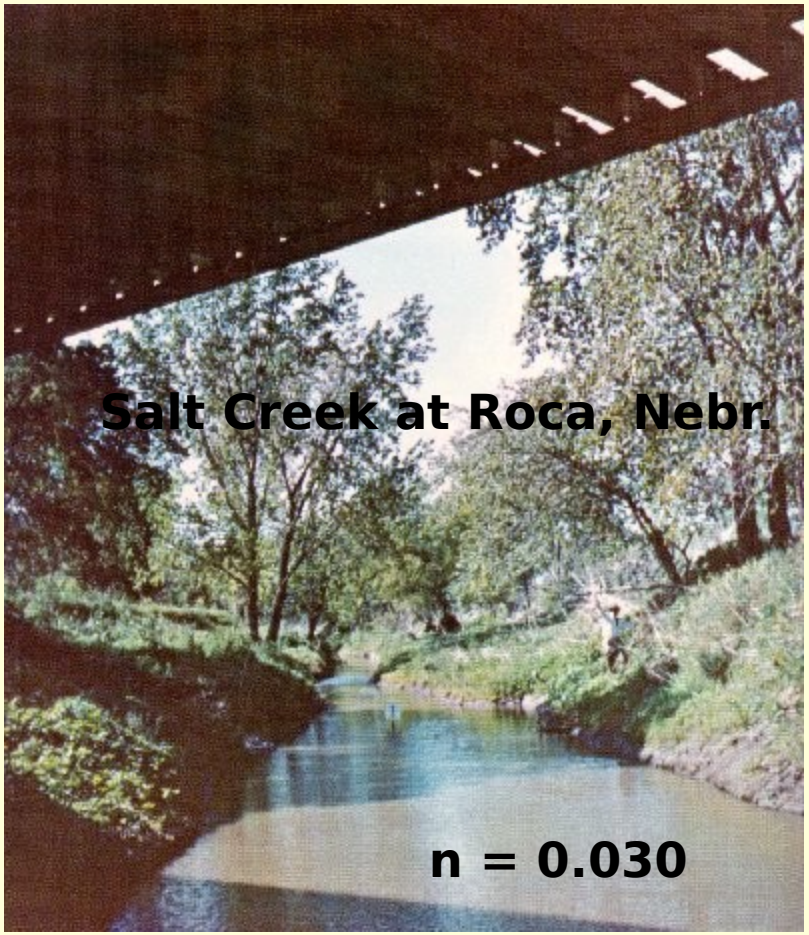

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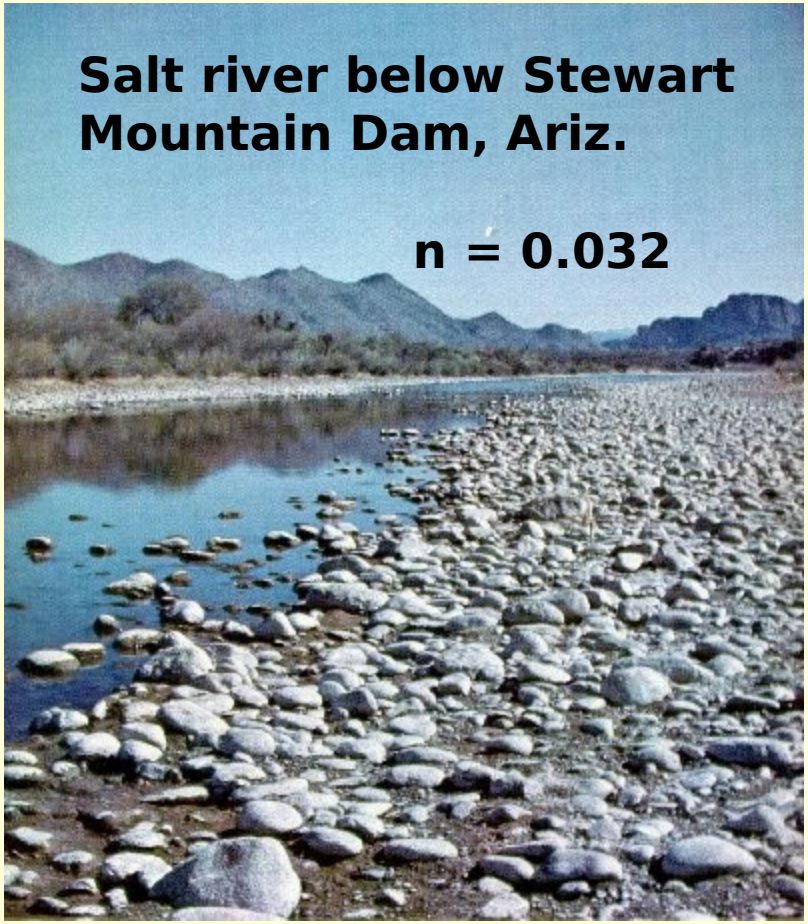

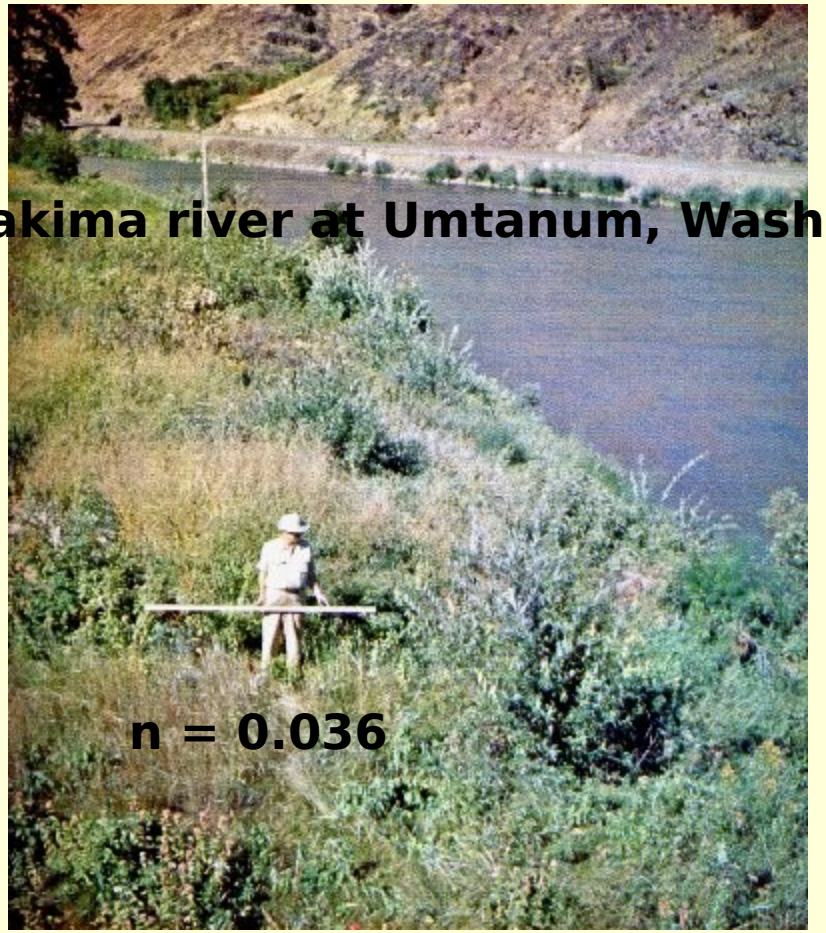

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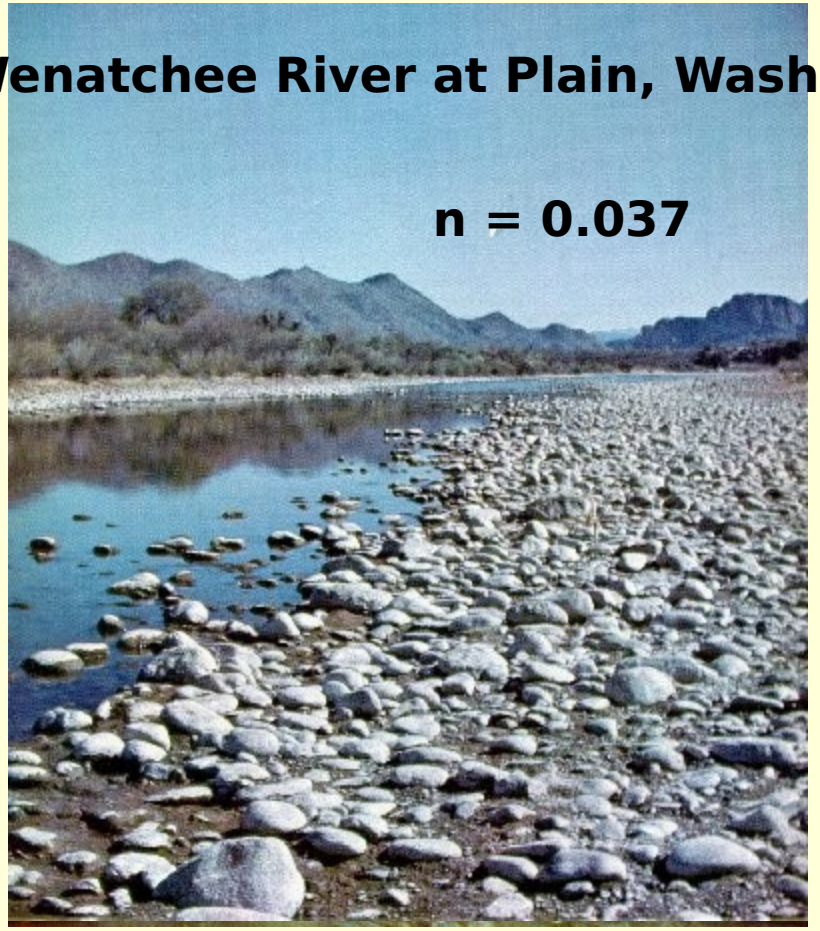
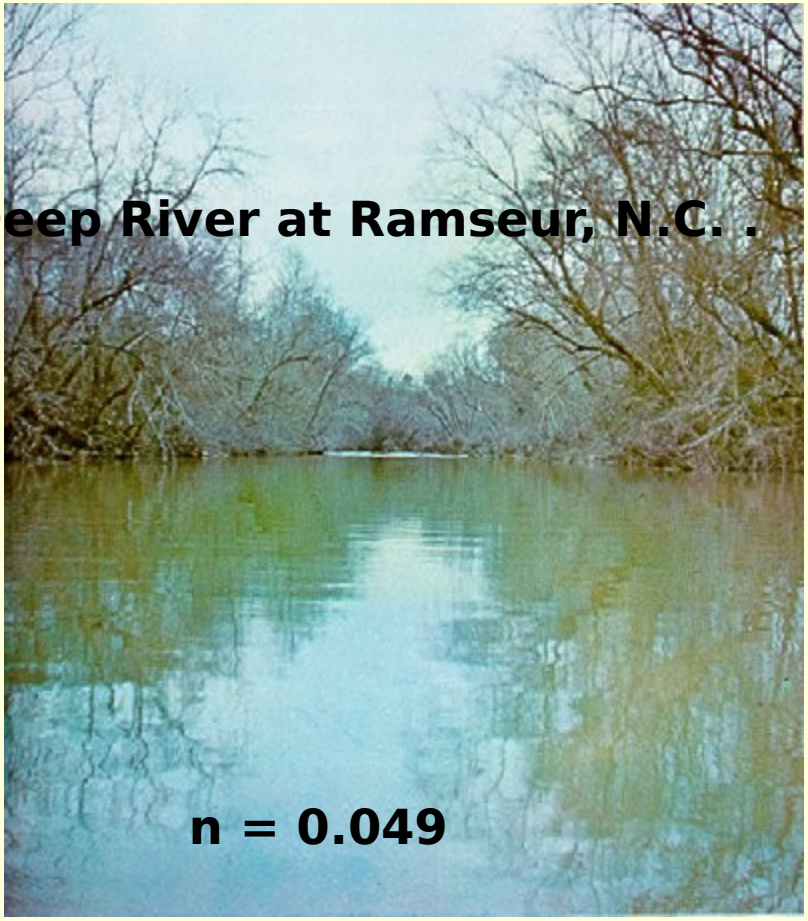
Wenatchee River at Plain, Wash.



Deep River at Ramseur, N.C. .



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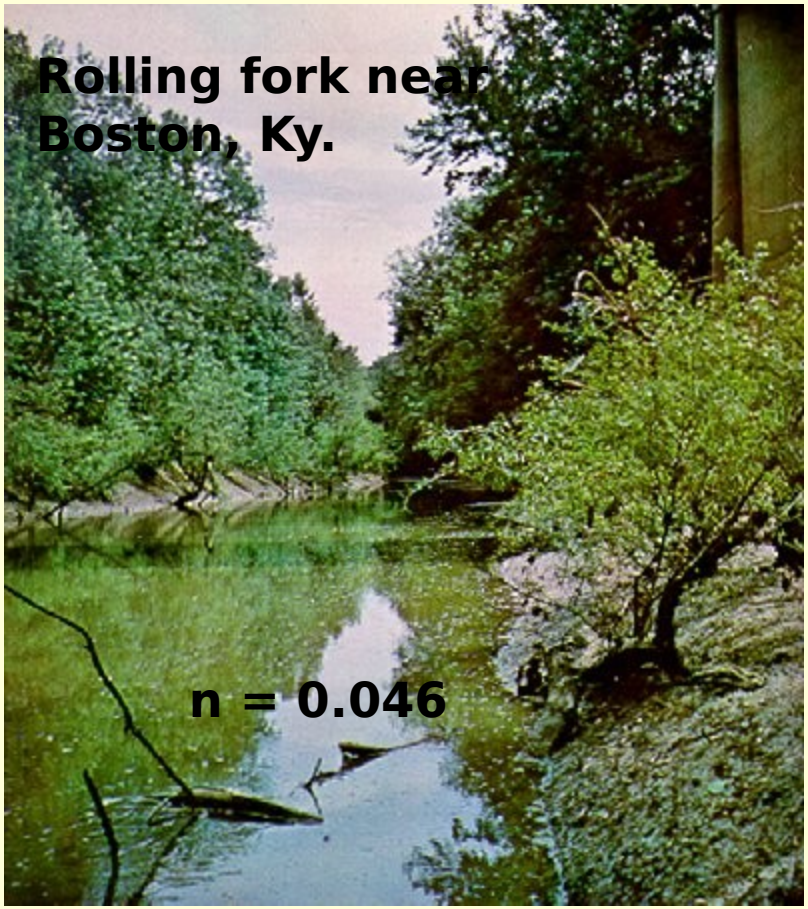

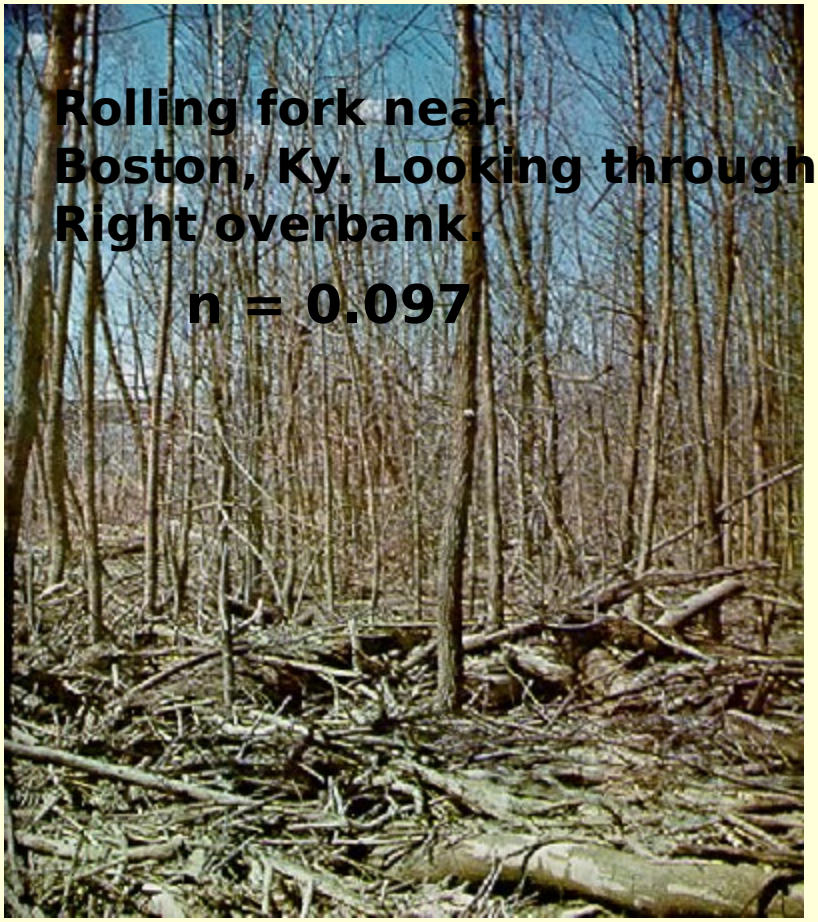

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Summary

- Hydraulic characteristics are affected by n
- n values change with time
- There is guidance on choosing n values
- Can verify n values by calibrating to data
- Computer models rely on user input on n values but also employ methods to vary n with depth